Identifying Cross Site Scripting Vulnerabilities in Web Applications

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The problem of Internet security and privacy

- Security and privacy are fundamental requirements for Web Applications
- 75% of the malicious attacks on the Web occur at the application level (Gartner Group)
- As more complex and automated Web Applications arise so does the probability of creating security loopholes.

The problem of Internet security and privacy

- Security and privacy are usually guaranteed by:
  - specific security systems (such as firewalls, or Intrusion Detection Systems) and software (such as antivirus or encryption software)
  - organisational changes to business processes finalised to improve security

- But developers do not build security into their applications, based upon the false assumption that another area of security will cover it

Cross Site Scripting (XSS)

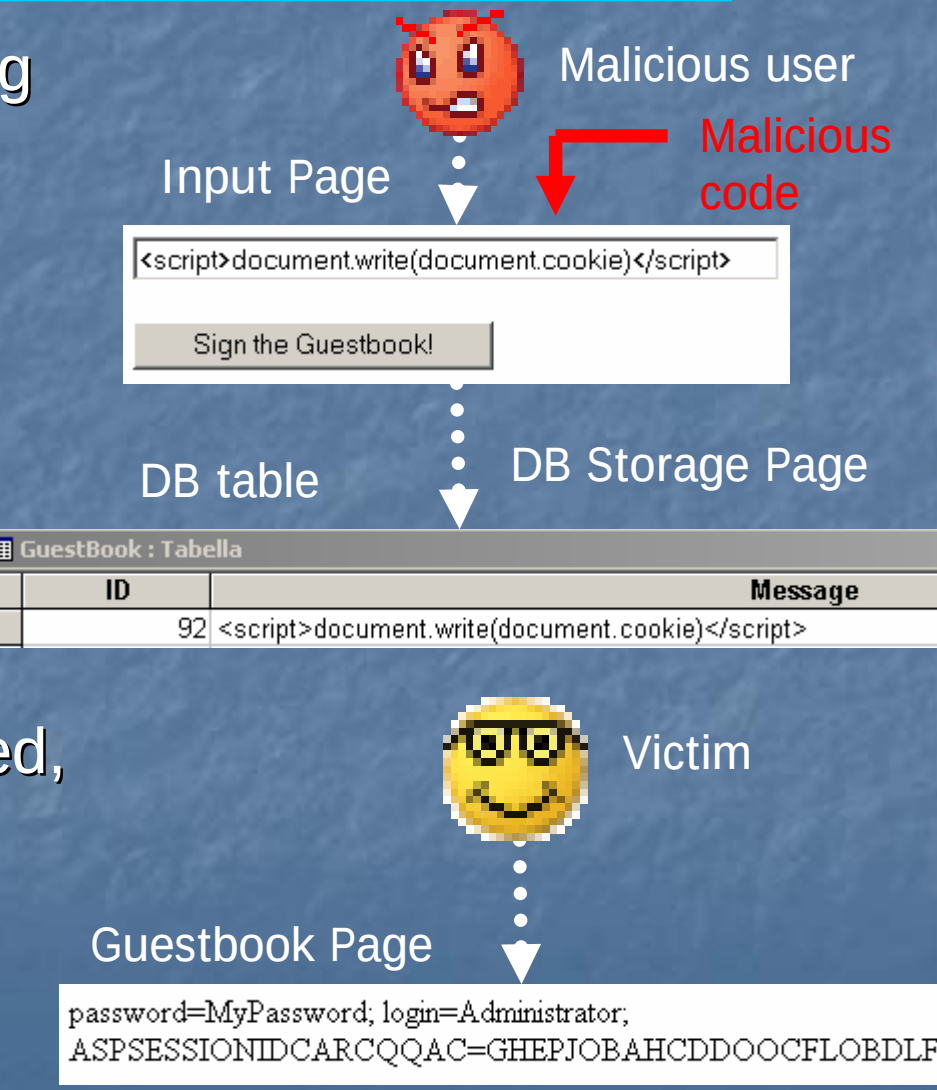
Cross-Site Scripting attack:

A client executes a page containing script code that has been injected from other sources

How can a malicious user perform a Cross Site Scripting attack?

First scenario

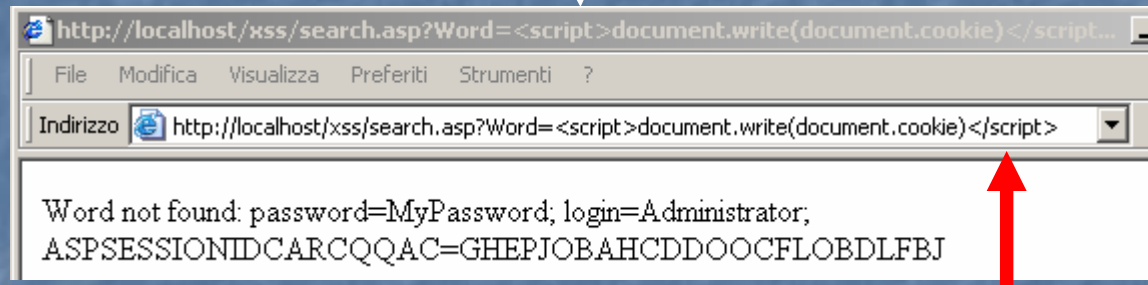
- Web Application implementing a Guestbook
- Malicious user inserting a message, containing script code
- The script code is stored into the database
- A victim open the Message page
- Since no checks are performed, the script code is sent to the browser as a message
- The browser executes the malicious script code



Second scenario

- A Simple Search form
- The victim unconsciously execute a link containing a malicious script code
- Simple Search server page write an error message...
- ... but this error message contains the script code, that is executed by the browser

Victim



Malicious code

Key factors of XSS vulnerability

- the exploits are very simple to carry out, and no particular application knowledge or skill are required;
- the attacks may bypass perimeter defences (e.g. Firewalls), cryptography, digital signatures and site trusting;
- it may be very difficult for the victim to know which web application allowed the XSS attack;
- it may be very difficult for the developer to know which element of the web application allowed the XSS attack;
- evolution of hypertextual language characteristics and browser capabilities may make it possible new attack strategies and make vulnerable a web application which was considered invulnerable.

Possible solutions

- To disable scripting language interpretation in browsers
- To install of a software proxy which intercepts malicious strings in input and/or output (Scott and Sharp, 2002)
- To introduce an input validation function immediately after every input statement contained in a Web page
  - To adopt this solution detection of vulnerabilities in source server script code is needed

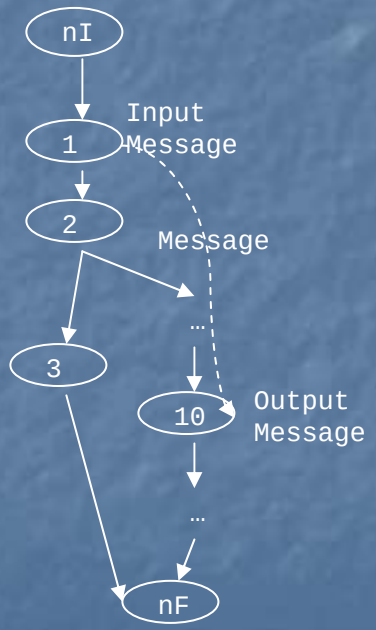
Detection and assessment of XSS vulnerabilities

Static and dynamic analysis of server pages are combined to detect and assess XSS vulnerabilities:

- Static analysis detects vulnerable pages and potentially vulnerable pages
- Dynamic analysis consists in the execution of a set of test cases reproducing XSS attacks

Potential vulnerability of a server page

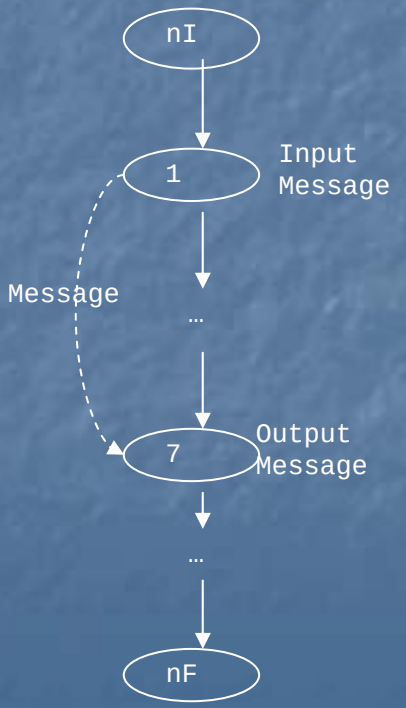
- A server page will be potentially XSS vulnerable if there are a variable v and two Input(v) and Output(v) nodes that are connected by a path on the CFG.




```
nI      <%
        'Read Message from input form
1       Message=request.form("txtMessage")
        'Check for string "script" in Message
2       if instr(1,Message,"script")>0 then
3         response.write("Forbidden")
4       else
          . . . open DB connection . . .
8         rs.open "Guestbook",conn,1,2,2
          'Store Message into the DB
9         rs.Addnew
10        rs("Message")=Message
11        rs.update
nF      end if
        %>
```

Vulnerability of a server page

- A server page will be vulnerable if there are a variable v, and two Input(v) and Output(v) nodes, such that all the paths on the CFG leaving the Input(v) node reach the Output(v) node, being def-clear with respect to v.

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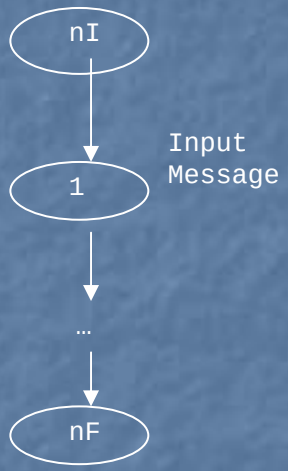
nF   %>
```

Invulnerability of a server pages

- A server page including an input data item that does not affect any output will be certainly invulnerable with respect to that input.




```
nI    <%
      'Read Message from input form
1     Message=request.form("txtMessage")
      . . . open DB connection . . .
5     rs.open "Guestbook",conn,1,2,2
      'Store a constant string into the DB
6     rs.Addnew
7     rs("Message")="One message received"
8     rs.update
nF    %>
```

Vulnerability conditions

Vulnerability predicates:

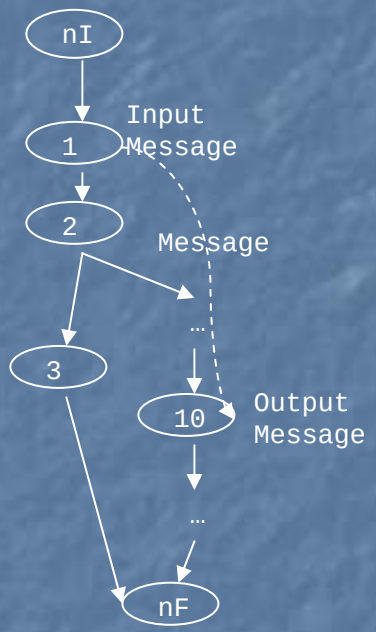
- A(v): There exists a path on the CFG between I and O nodes.
- B(v): The O node postdominates I node.
- C(v): Each path between I node and O node is a def-clear-path

(obviously, B(v)=>A(v) and C(v)=>A(v))

Vulnerability conditions:

- PV) $\exists v \in P$: A(v) => P is potentially vulnerable with respect to v => P is potentially vulnerable
- V) $\exists v \in P$: B(v) AND C(v) => P is vulnerable with respect to v => P is vulnerable
- NV) $\exists v \in P$: NOT(A(v)) => P is not vulnerable with respect to v

Examples (1)

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        %>
```
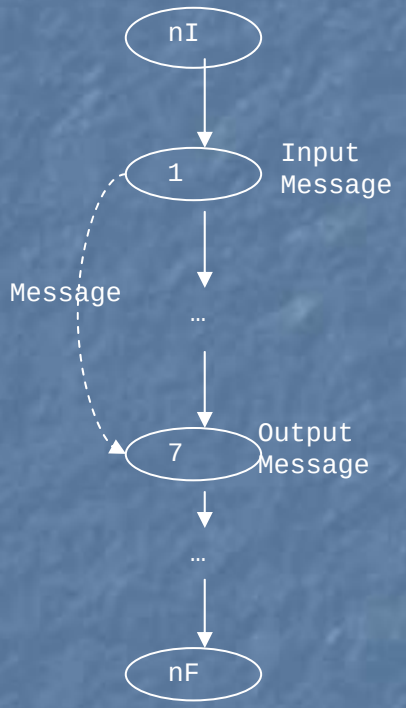

Predicate values			Condition			Input variable
A	B	C	V	P	NV	
T	F	T	F	T	F	Message

The server page is potentially vulnerable with respect to the variable *Message*

Examples (2)

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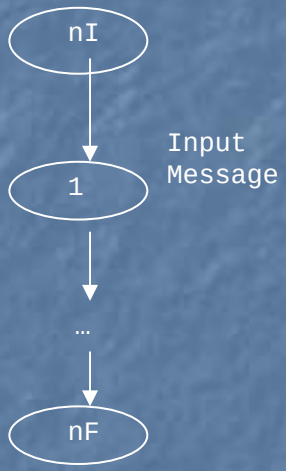
8    rs.update
nF   %>
```

Predicate values			Condition			Input variable
A	B	C	V	P	NV	
T	T	T	T	T	F	Message

The server page is vulnerable with respect to the variable *Message*

Examples (3)

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```

Predicate values			Condition			Input variable
A	B	C	V	P	NV	
F	F	F	F	F	T	Message

The server page is not vulnerable

Static analysis

1. Identify the input and output nodes of the CFG of the page P;
2. Identify all paths leaving the input nodes on the CFG;
3. For each path leaving an input(v) node and reaching an output(v) node, verify if the path is def-clear with respect to v;
4. Evaluates A, B, and C predicates' values with respect to v;
5. Evaluate the vulnerability of page P, by the PV, NV, and V conditions.

With reference to the second step of this process, in order to cope with the complexity of identifying all paths leaving the input nodes on the CFG, the analysis can be limited to a set of linearly independent paths extracted from the CFG.

Dynamic analysis

- Tthe presence of a vulnerable page doesn’t imply that a XSS attack can be performed. To assess if a Web Application is actually vulnerable to XSS attacks, dynamic analysis may be performed.
- A vulnerability should be corrected and eliminated by the developer. The semantic of the source code of pages containing potential vulnerability should be analysed by the developer.
- A testing strategy involving the execution of a set of attack test cases must be followed

Testing strategy (second scenario)

```
FOR EACH vulnerable or potentially vulnerable
    page P of the Web Application
  FOR EACH input field I of page P causing
    vulnerability
     Define a set S of XSS attack strings
     FOR EACH s ∈ S
        EXECUTE server page P with
        input field I=s
        Check for attack consequences
```

Testing strategy (first scenario)

```
FOR EACH vulnerable or potentially vulnerable page
    P of the Web Application
  FOR EACH input field I of page P causing
    vulnerability
    Define a set S of XSS attack strings
   FOR EACH s ∈ S
      EXECUTE server page P with input field I= s
     FOR EACH test case T from the test suite
        EXECUTE test case T
        Check for attack consequences
```

Case study

- Real world open source Web Applications implemented in PHP and ASP has been analysed
- An example: Snitz Forum, version 3.4.03 (http://forum.snitz.com)
- Vulnerability situations has been detected using static analysis
- A vulnerability to XSS attacks of the second type has been confirmed by dynamic analysis

An example

An example of vulnerability is contained in the following source code:

```
Response.Write “<input type=""text"" name=""Search""
   size=""40"" value="""" & Request.QueryString("Search") &
   """><br />" & vbNewLine
```

This line of search.asp page contains a vulnerability: the value of an input variable (Search) will be sent to the client browser with no checks. The following test case perform a XSS attack redirecting Client Cookie values to a page of attacker’s server :

```
“><script>location.URL=‘http://www.attackersite.com/atta
cker.cgi?’ + document.cookie) </script>
```

An example

This vulnerability is also reported by Bugtraq web sites (http://www.securityfocus.com, http://msgs.securepoint.com/bugtraq/) and it has been corrected in the next version (3.4.04) of the forum

```
Response.Write ”            "<td bgColor="""" &
strPopUpTableColor & """ align=""left"" valign=""middle"">
<input type=""text"" name=""Search"" size=""40"" value="""
& trim(ChkString(Request.QueryString("Search"),"display"))
& """><br />" & vbNewLine & _
```

Conclusions

- A WA should be intrinsically secure, by adopting secure programming practices, in order to preserve its invulnerability as the execution environment changes.

- This paper proposed an approach for assessing the XSS vulnerability of an existing WA based on static and dynamic analysis of source code: Static analysis criteria have been defined to individuate vulnerable Web pages, while dynamic analysis strategies have been proposed to test the actual vulnerability of the Web Application including the vulnerable pages.

Future works

- To support static analysis with automatic tools
- To integrate dynamic analysis with test case execution tools
- To assess the effectiveness of the approach with a wider set of applications